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United States Patent Application for

A Motor Pulse Controller

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Cross Reference to Related Applications

This patent application is related to and takes priority from United States Provisional Patent Application number 60/454,066 filed on March 12, 2003 entitled "A Motor Pulse Controller" by Mallappa Guggari and Keith Womer and United States Provisional Application number 60/499, 240 filed on August 29, 2003 entitled "A Motor Pulse Controller" by Mallappa Guggari and Keith Womer.

Background of the Invention

Field of the Invention

The present invention relates generally to the field of surface to down hole communication techniques for an oil rig. The invention pertains in particular to a direct interface which intercepts existing commands going to existing oil rig equipment and superimposing additional commands onto the existing commands to manipulate drilling mud pressure and/or other physically perceptible influences which a down hole tool or other device can detect and interpret.

Background of the related art

Varying mud pressure to command a down hole tool is well known in the art. Currently known techniques for manipulating mud pressure to communicate a command from the surface to down hole equipment are inefficient. These known mud pressure

command systems require large, heavy equipment to be added to the oil rig to manipulate mud pressure. One example of a known mud pressure command system is the Halliburton Geo-Span™ downlink system. The Geo-Span™ system diverts mud flow to reduce mud pressure to change the azimuth and inclination of a steerable drilling system. The Geo-Span™ system requires the addition of a bulky high pressure mud diversion valve and controller. Such an addition is expensive and requires the utilization of additional rig space which is at a premium. Thus, there is a need for a down hole communication system that does not require the addition of the bulky mud diversion valve to existing equipment.

Some systems require operator to manually switch the mud pump on and off to create a pressure fluctuation. This pressure fluctuation is used to signal or command a down hole device which senses a change in the mud pressure. This manual technique is slow (on the order of several minutes to transmit a simple command). Moreover, these manual commands are subject to error due to the variation between operators' implementations of the manual commands. Thus, there is a need for a faster and more precise communication method and apparatus for communicating with down hole equipment.

Summary of the invention

The present invention provides a method and apparatus for communicating control commands from an oil rig surface location to a down hole device. The control commands comprise one or more than one physically detectable changes which are sensed by the down hole device. When using more than one physically detectable changes, the physical changes can occur simultaneously or sequentially. The present invention performs specific causal acts by intercepting existing control signals and superimposing one or more commands on top of the existing control signals. The superimposed command causes physical changes, such as a variation in mud pump pressure and/or rotation that can be sensed by a down hole tool or a device.

Additionally, the superimposed wave form or command may cause a variation in drill string rotation speed, addition of a tracer to the drilling mud or transmission of an acoustic pulse down hole. The superimposed command may also manipulate a draw works to vary the weight on bit, or vary the speed of a mud pump to change drilling mud pressure, or manipulate a top drive to change rotation speed. The physical change (e.g., a change in rotation, mud pressure, tracer presence, or an acoustic pulse) is sensed by a down hole device. The down hole device interprets the physical change as a command to the down hole device that it is to perform an operation such as adjusting an operating parameter such as a drilling angle.

Brief Description of the Drawings

Fig. 1 is an illustration of a preferred embodiment of the present invention in communication with a remote location, lap top computer, mud pump, top drive, draw works and rotary;

Fig. 2 is an illustration of a preferred controller;

Fig. 3 is an illustration of a variety of pulse and pulse string characteristics, which are configurable via a graphical interface or by a command on a laptop computer or from a remote location;

Fig. 4 is an illustration of a preferred embodiment of the present invention showing a system for generating commands to down hole equipment;

Fig. 5 is an illustration of a command generator, which translates a user input into an equipment command for transmitting to a down hole equipment;

Fig. 6 is an illustration of a system utilizing the present invention to control a down hole device in a drilling rig using a user interface to generate commands; and

Fig. 7 is an illustration of a input sequence for entering a drilling orientation command.

Detailed description of an embodiment of the invention

The present invention provides a simple controller to command existing equipment to cause physically perceptible changes in the down hole environment. A down hole tool or a device detects the physical changes and interprets them as a command. The command causes the down hole tool or a device to perform an act such as changing the drilling angle. The present invention interfaces with existing oil rig equipment without the need to add a bulky mud diversion valve to change mud pressure. The present invention eliminates the need to perform manual manipulation of the existing oil rig equipment to command a down hole tool.

The present invention superimposes commands on a selected SCR controller or other equipment to generate predefined changes in a motor speed or another equipment's output which causes a change in mud pressure or some other physical change which can be detected at down hole. In one example, the present invention generates variations in mud pressure or in the flow rate of the drilling mud by changing commands sent to a SCR controller. The SCR controller then manipulates mud pressure by changing the mud pump speed. The present invention can also generate variations in mud pressure by changing commands sent to a controllable choke. The present invention can also generate rotational speed variation commands in top drives or rotaries to generate a perceptible variation in the rotation speed of the drilling mechanism. The present invention is also used to generate a variation in the weight on bit or speed of hoisting and lowering via manipulation of a draw works. The present invention can also inject tracers which can be electronic or doped chemically or with nuclear isotopes. The present invention enables drillers or other users to send predetermined sequences or combinations

of physical influences which are detected and interpreted as commands by a down hole tool or a device. These predetermined commands can be one shot, multiple shots or continuous or periodic bursts of physically perceptible changes.

In one example of the present invention, a controller is designed around and incorporates an industry standard embedded controller to provide a reliable and familiar operation. The controller is packaged in a rugged housing to meet the rigorous specifications for industrial oilrig site usage. In the present example of the invention, a small easily installed lightweight controller is provided with an intuitive user interface. A user interface is provided to enable a user to easily command down hole operations, such as drilling angle or data reporting rate by manipulation of a physically perceptible physical parameter.

In the present example of the invention, a controller is provided which is designed to interface seamlessly with all major silicon controlled rectifier (SCR) drives as well as the alternating current (AC) drives. In the current example of the invention, the controller provides operational flexibility. In a preferred embodiment, the present invention provides a controller designed to provide a communication interface with three SCR drive systems at a time. Utilizing the present invention, a rig operator or other user can easily communicate with the controller to superimpose command data upon existing rig control signals. The superimposed data is used to send command data to down hole tools or devices by manipulating the rig equipment to effectuate a perceptible physical parameter in the operational state of the rig. The user can define the data using graphical interface tools provided by the user interface of the present invention to avoid costly mistakes from human error induced variances in manual operation. The present

invention enables product and service providers to focus on maximizing reliability by providing a familiar interface that can be bypassed at will. The present invention offers additional combinations of physical influences for generating commands.

As shown in **Fig. 1**, in the current example of the invention, a motor pulse controller **100** of the present invention interfaces with three independent SCR drive systems associated with an oil rig. In the present embodiment, each single motor pulse controller **100** interfaces with three SCR drive systems or controllers. Additional motor pulse controllers **100** are combined with the motor pulse controller **100** to provide an interface with additional SCR drive systems/controllers. These SCR drive systems/controllers control rig devices, such as a mud pump **102**, a rotary table **104**, a draw works **110**, a top drive **106** or another equipment controller associated with the oil rig. In the current example of the invention, a controller **100** sends command signals through one of the SCR drives to change mud pressure, rotation speed or weight on bit. These changes cause a perceptible change in a physical parameter that can be sensed down hole. Commands are initiated by a user or an automated source **103**. The user can send commands from a remote location **109** or through a local controller such as a lap top computer **101**. The selection of the SCR drive to use can be easily selected by a switch **108** located on the front plate of the unit located on the rig control floor **107**. Switch **108** is shown in more detail in **Fig. 2**. The user or driller can completely bypass this unit by placing switch **108** in "off" position.

As shown in **Fig. 2**, in the current example of the present invention, a processor **200** is remotely commanded by a user or an automated source via communication port **120**. The user commands causes the processor **200** to send encoded pulses (as shown in

Figure 3) or predefined offsets superimposed on top of the existing control signals **111** which are sent to the selected motor controller. The user commands manipulate and create a variation in the SCR motor control outputs. In the current example of the invention, a PC-based user-friendly graphical interface program translates the user inputs into controller commands. The user need only enter a simple graphical command via the user interface **618** shown in **Figure 6**. The user need not manipulate or specify actual motor pulse waveforms from user interface **618** at remote location **109**, lap top **101** or rig floor **107** as this is performed by processor **200** of the present invention. That is, the present invention takes the user's simple graphical or textual input from user interface **618** and generates an appropriate controller command for the designated equipment. The present invention can also take commands from automated sources like dynamic models or third party controllers at interface **618**. The command can augment a SCR motor control signal or another control signal motor control to effectuate the user's designated command. A user can easily modify the command data via the user interface **618** and send that command data to the processor **200** using TCP/IP Ethernet link **120**. Use of TCP/IP link **120** allows various other types of devices like embedded controllers or PDAs or another wireless device to send command data directly to this processor **200**.

Existing SCR signals **111**, from the existing conventional driller console on the oil rig floor **107** enter switch **108** through input terminals **111** and exit switch **108** at output terminals **113** as signals to an SCR system or another controller. Depending on the state of the switch **108**, the existing SCR signals **111** either bypass processor **200** or pass through processor **200**. Processor **200** superimposes commands on a selected existing SCR signal **111** when switch **108** is in an "on" position 1,2 or 3. Control signals **111** are

also commands to SCR controllers or other controller rather than an SCR controller to vary rotation speed, add a tracer, vary weight on bit or initiate an acoustic signal which are initiated from user interface **618**. Additional commands can be generated from user interface **618** to accommodate new drivers or equipment to be added to the oil rig system.

Turning now to **Fig. 3**, an example of command **300** which is superimposed on an existing command **317** is shown. The shape of a command pulse train can be defined by specifying pulse duration (T-on **310** and T-off **312**) and amplitude **316**. In a preferred embodiment, the user designates a particular command at the user interface **618**. The processor of the present invention receives a user input and specifies the pulse shape, periodicity and duration to effectuate the desired command. The present invention takes the user input from the user interface specifies the corresponding pulse duration by configuring the pulse shape, periodicity, duration, turn on and turn off times for each command pulse. The command pulse rise and fall time response **314** (Φ), that is, the rise/fall time of each pulse can be configured as a predefined wave shape, e.g., similar to a portion of a sine wave. The present invention can also limit the modifications to existing command based on preset conditions or dynamic state of the equipment or operational limits imposed by third party sources. In the present example, the processor defines the frequency component of this sine wave as an input based on user input and predefined equipment commands. The pulse amplitude **316** (A) is also configurable to designate particular equipment commands. In the present example, the user defines the amplitude of the pulse by providing a text or graphical command which the present invention interprets and calculates the corresponding command amplitude A. The controller generates pulses of magnitude A above or below the current value of the motor

output **317** based on configuration of oil rig equipment to be controlled and the command specified by the user at user interface **618**. In the present example of the invention, the controller **200** also generates pulses with current value **317** minus A as minimum level and/or current value plus A as a maximum level.

As shown in **Fig. 3**, in the present example, various command pulse modes are supported. Essentially any desired pulse string modification mode is supported, however, the present example illustrates three modes for example. The first command mode is the Single Pulse Train Mode **320**. In Single Pulse Train Mode, when a user pushes the send/stop button, a single set of pre-defined pulses is sent only once. In the Fixed Set Of Pulse Train Mode **330**, when the user pushes the send/stop button, pre-defined sets of pulses are sent at defined intervals for a fixed number of times. The processor **200** defines the repeat interval as well as the number of iterations of the signal. In the Continuous Pulse Train **340** mode, when a user pushes a send/stop button, a pre-defined set of pulses is sent at defined intervals continuously until send/stop button is pressed again.

Turning now to **Fig. 4** a system for generating commands to down hole equipment is illustrated. A user inputs a command chosen from a pull down menu on user interface **618**. The command is shown on user interface **618** as a human readable instruction such as, "steer down 30 degrees during drilling." The human readable instruction may also be an icon indicative of the desired command. The command may also come from automatic source like dynamic modeling or third party controller. In the present example, an operator selects a steer command and selects the orientation and degree of change in orientation, such as down/up, 0-90 degrees. The user interface **618** sends the user

command to the command generator **402** which resides in processor **200**. The command generator is detailed in **Fig. 5** and discussed below.

The command generator translates the user input command to an equipment command based on the system state. The command generator **402** sends the equipment command it generated, to the drilling console interface **404**. The drilling console interface **404** superimposes the user command on existing signals **111** coming from drilling console **406**. The equipment command comprises, for example, a stream of control pulses discussed above for signaling the controllers **420, 421, 423, 425** and **427** to implement a change in rotation, mud pressure, weight on bit or tracer concentration.

As shown in **Fig. 4**, the compact drilling console interface **404** is easily installed between existing drilling console **406** on the drill rig floor **107** and controllers **420, 421, 423, 425** and **427**. Thus, the present invention is easily retrofitted in the field without extensive modification to existing oil field equipment. The present invention provides additional lines **411** which are spliced onto communication lines **111** running to and from existing drilling controller **406.** Switches **108** divert incoming signal **111** to bypass the drilling console interface **404** when closed. The incoming signals **111** are sent through drilling console interface **404** when switch **108** is open. In a preferred embodiment only one of three inputs **111** are sent through controller **404** at a time. A single drilling console interface **404** preferably handles three sets of inputs **410**. Thus, one or more additional drill console interfaces **405** can be added for handling additional sets of inputs **111**.

Controllers **420, 421, 423, 425** and **427** receive equipment commands from command generator **402**, interpret the equipment command and issue an equipment

specific command to control a down hole device accordingly. As shown in **Fig. 4**, as an example, a motor controller **420** is commanded to manipulate a device, such as a draw works **424**. The draw works **424** changes weight on bit. This change in weight on bit is sensed by a down hole weight on bit sensor **426**. Similarly, motor controller **421** commands RPM generator **430** such as a top drive or rotary. The command changes the rotation rate, which is sensed by a down hole rpm sensor **432**.

Acoustic/Tracer controller **423** commands a tracer injection or generation of an acoustic signal via tracer/acoustic system **436**, well known in the art, into the mud supply. The tracer comprises a traceable fluid such as detectable by a down hole tracer/acoustic detector **438**. The tracer may also comprise injection and removal of micro spheres, which can be detected by a down hole tracer/acoustic detector **438**. The injection and removal of such micro spheres is well known in the art for the purpose of changing the density of drilling mud. The inventors, however, are aware of no application in which micro spheres have been used as a command generator, either alone or in combination with another command such as a change in mud pressure or drill string rotation speed. The micro sphere tracer or acoustic signal is preferably detectable by a down hole tracer/acoustic detector **438** by detecting a change in density or by sensing a physical characteristic such as an electrical characteristic unique to the tracer spheres. The micro sphere tracer can also contain electronic components capable of sensing, storing or transmitting data which can be detected by a down hole device.

Choke controller **425** receives commands and sends commands which control choke **442** for restricting mud flow for modulating the mud pressure for sensing by a down hole pressure detection device **444**, well known in the art. Motor controller **427**

receives commands and sends commands which control mud pumps **452** for restricting mud flow for modulating the mud pressure for sensing by a down hole mud pressure sensor device **454**, well known in the art. Each sensor **426, 432, 438, 444** and **454** can be associated with but separate from down hole equipment. Each sensor **426, 432, 438, 444** and **454** sends a command **413, 417, 419, 421** and **423** to the down hole equipment.

In an alternative embodiment, the down hole sensors **426, 432, 438, 444** and **454** are contained in a central sensor assembly **446** (shown as a dotted line in **Fig. 4**) which houses sensors **426, 432, 438, 444** and **454** senses changes in weight on bit, rotation, tracers and mud pressure and sends a command **415** to a down hole equipment.

Turning now to **Fig. 5,** the command generator which runs as a process in processor **200** is shown in schematic form. As shown in **Fig. 5**, the command generator translates a user input into an equipment command for transmitting to a down hole equipment. The command generator **402** receives a user command **510** from the user interface **618**. The command generator checks the system state **512** to determine which equipment is running and actually connected to the system. A current system operational state subsumed in the system state comprises, for example, current bit weight, current mud pressure, current tracer concentration and current tracer type present and current operational (on/off/offline) state for equipment in the system.

The command generator selects a command based on the system state stored in the processor memory **201**. For example, if an equipment for causing a change in rotation, an equipment for causing a change in mud pressure, an equipment for causing a change in bit weight, an equipment for sending an acoustic pulse down hole and an equipment for changing tracer presence are all available in the system state, then a

command using all of these available physical parameters can be sent down hole. The command sensed by the down hole device can be a combination of all available physical influences perceptible down hole. If only a subset of equipment is available to cause changes in physical parameters, then the commands sent down hole comprise only those physical parameters which can be generated by the available equipment.

The command generator generates a command, which comprises one or more physical influences such as for example changes in pressure, weight on bit, tracer concentration, acoustic pulse generation and rotation speed to represent a command detected and, understood by a particular equipment located down hole. Additional physical influences can also be used as commands. The command generator, via the system state knows the type of equipment available, the equipment manufacturer and the type of sensor associated with the down hole equipment. The command generator looks at what physical parameters the down hole device can sense and sends and appropriate equipment command to equipment controllers **518**, which correspond to controllers **420, 421, 423, 425** and **427** in **Fig. 4**.

In the present example there are five primary detectable physical influences (weight on bit variation, drill string rpm variation, variation in the presences or type of acoustic signal or a tracer, and mud pressure variation.). These physical influences are physically perceptible by down hole detectors **413, 417, 419, 421** and **423**. Thus there are five primary influences that can be present or not present to represent a total of thirty-two commands or states in which these five primary influences appear. These five primary influences are used to represent thirty-two command states which can be transmitted to and perceived by down hole equipment. Additional physical influences

can be added. Thus, if there are M available primary physical influences, some of which may not be known today, there are $2^M - 1$ command states or command available which can be derived from M on off state physical influences, when the physical influences are used concurrently. With each of these primary command states there are numerous additional secondary command states represented by perceptible differences within a primary physical influence. For example, within a single primary influence such as rotation speed (rpm), a down hole equipment can be signaled with a different command for each secondary state of a primary influence of 10 rpm, 20 rpm, 30 rpm and 40 rpm. Also, if the M physical influences are performed serially, then numerous additional commands are available according to various sequences of physically perceptible parameters.

Turning now to **Fig. 6**, a preferred embodiment of the present invention is shown with user interface **618**, top drive **106**, choke **442**, driller console **406**, tracer and acoustic controller **436** and draw works **110.** These elements operate together as described above to send commands through drilling mud **625** and drill string **612** manipulation to down hole sensors **626** which command the down hole device **624**.

Turning now to **Fig. 7**, an illustration of the present invention is shown soliciting a user input from the user interface **618** such as, "select drilling direction." The user input from user interface **618** can be textual, graphical, aural such as a verbal command or a computer generated as in modeling. A drill direction screen **700** is presented to the user who inputs the desired drilling direction. For example, a user can input drill down at a 30-degree angle, at block **700**. At block **710** in the current example, the present invention determines the current drilling orientation and the change of direction

requested, that is, the change from the current orientation to achieve a new orientation as requested by the user. The present invention then verifies the system state **730** to determine the operational state of the available equipments to ensure that a command is available. For example, if the rpm are already at a maximum, for example, over 400 rpm, then a command requiring an increase in the rpm would not be available and an error message **740** is generated. If the system state is within an appropriate range, then the present invention proceeds to the command generator **510** where the human readable command provided by the user interface **618** is encoded into an equipment command. The equipment command is then superimposed on the existing control signals and sent to the controllers as shown in **Fig. 5**. The user input and system configuration tasks, some of which are shown in **Fig. 7** can be distributed between controllers **100, 101** and **109**. A third party controller 103 can also be used to input commands and to dynamically change the operating parameters of the oilrig.

For example, the user interface for a user inputting commands to the system and for a user receiving feed back from the system can be distributed between **100, 101** and **109**. The user commands and feed back can be graphical, textual or aural. A user can issue a command, such as change the steering angle of a down hole device by 40 degrees. Another task that can be distributed between the processors **100, 101** and **109** is the collection of system status. System status comprises system configuration and operational states, such as a speed at which a motor is running, how many motors are assigned, what kind of tracer or concentration is being used, what kind of acoustic signal is available, and what kind of top drive is attached to the system. This system status is communicated either directly or indirectly to the user. The direct communication to the

user comprises aural, graphical or textual output to the user from **101, 100** and/or **109**. Indirect communication to the user comprises notifications that a command cannot be performed because of system states, which inherently includes system state information.

System configuration is distributed between user input processors **100, 101, 109** and also distributed to third party configuration processor **103**. Static configuration is normally performed from user input terminal processors **100**, 101 and **109**, whereas dynamic configuration is usually performed from third party configuration processor console **103**. Static configuration is usually performed by setting system parameters such as minimum and maximum rpm rates for all operations states. Dynamic configuration is performed for temporarily setting and usually temporarily changing a system parameter such as minimum and maximum rpm rate for a specific and temporary condition.

For example, a static rpm operating range specified as a minimum and maximum might be set from user input processors **101, 100** or **109**. For example a maximum of 400 psi mud pressure is set as a static configuration parameter. Thus a command can be issued that would raise the mud pressure to 300 psi to signal a down hole device. This command is allowed by the processor because the 300 psi does not exceed the maximum mud pressure psi of 400 psi. A third party at **103** can change the static maximum mud pressure configuration from 400 psi to a dynamic mud pressure maximum of 250 psi. Such a change would override the static maximum and set the mud pressure maximum temporarily to 250 psi. Once the dynamic mud pressure maximum of 250 psi is entered, the command that would raise the mud pressure to 300 psi to signal a down hole device could no longer be performed because it exceeds the dynamic mud pressure maximum of 250 psi. The user would be notified that the requested command cannot be performed.

The processor, however, may change the command from a mud pressure command to another physical influence such as tracer, rpm, acoustic or weight on bit in order to perform a command that will accomplish the same thing as the mud pressure command without exceeding the mud pressure maximum. For example, if a steer 40 degrees command can be implemented with a mud pressure pulse of 400 psi or a rpm pulse of 400 rpm, if the mud pressure pulse violates the system maximum, an rpm command would be used to command a steer 40 degrees command.

The present invention has been described as a method and apparatus operating in an oil rig environment in the preferred embodiment, however, the present invention may also be embodied as a set of instructions on a computer readable medium, comprising ROM, RAM, CD ROM, Flash or any other computer readable medium, now known or unknown that when executed cause a computer to implement the method of the present invention. While a preferred embodiment of the invention has been shown by the above invention, it is for purposes of example only and not intended to limit the scope of the invention, which is defined by the following claims.